1098/ DFF05

REDACTED

ORCKIT
Communications Ltd
38 Nahalat Yitzhak St.
Tel-Aviv 67448, Israel
Tel. +972 3 696 2121
Fax. +972 3 696 5678

ADSL MODEM HYBRID DESIGN

FIELD OF INVENTION

The present invention relates to XDSL MODEMs connected to telephone lines that need to attenuate its own transmission echo while receiving a signal that was transmitted from another MODEM.

The hybrid description is given for ADSL modem, but it can be implemented in other similar telecommunication systems.

BACKGROUND OF INVENTION

ADSL MODEMS need a hybrid circuit in order to attenuate its own transmission echo in order to maximize the dynamic range of the receiving path of the MODEM.

The received signal is picked off the secondary of the line receiver. At that point, the transmitted echo signal, which is inseparable from the received signal, had its characteristics affected by the line transformer and the line itself (assuming a long line, that minimizes the influence of the opposite MODEM).

At the same time, a sample of the transmission signal is taken from the output of the line driver and is processed to get a replica of the transmitted echo signal.

Subtracting the two signals attenuates the transmit echo signal by an amount that is correlated to the matching of the reconstructed echo signal and the echo signal itself, leaving the received signal with a much better received to transmit echo signal ratio.

REDACTED

SUMMARY OF THE INVENTION

The invention includes some key points that differ the circuit topology in this invention from other hybrid circuits that are used in MODEMS:

- Compensation of the line transformer.
  It will also compensate for a high pass filter that incorporates the line transformer or is connected to the line transformer, but the compensation will be effective only at frequencies somewhat higher than the cut-off frequency of the filter. The exact frequency from which the compensation is effective depends on the specific design of the high pass filter.
- Compensation of the varying impedance of the line.
- The transmit echo reconstructing circuit is an all passive circuit that maximizes linearity and minimizes distortion.
- Subtraction of the transmitted signal is done by passive components, so only the subtracted signal with the enhanced receive to transmit signal ratio enters the receive path amplifiers, minimizing distortion and maximizing the dynamic range.
- Parallel connection of two series RC branches that are connected between low impedance points, which cancels the interaction between the branches and allow to change one branch without affecting the other.
- Minimum of components count.

DETAILED DESCRIPTION OF THE INVENTION

The ADSL MODEM is a sophisticated MODEM that has overlapping transmit and receive frequencies.

Such a MODEM has a receiver that needs to extract the received signal from the line, while attenuating as much as possible its transmission.

This function is performed by the Hybrid, a passive circuit that is connected between the line driver amplifiers and the line transformer and directs the received signal to the receive path while attenuating the MODEM's transmission.

The general drawing of the circuit is shown in Fig.1.

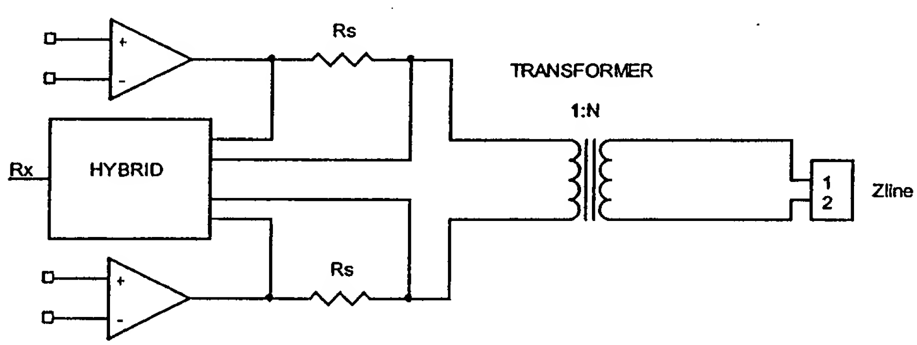

Fig. 1

The explanation of the hybrid circuit developed for the ADSL MODEM will be done in steps, from an ideal simple case to the final practical circuit. A single ended (unbalanced) circuit will be used for the explanation for simplification.

1. Ideal transformer, constant Ohmic line impedance (Rline).

The transformer is ideal which means that it transforms impedance from its primary (line side) to its secondary (circuit side) according to its turns ratio, while its parallel inductance is infinite.

The transmit circuit in this case is shown in Fig. 2.

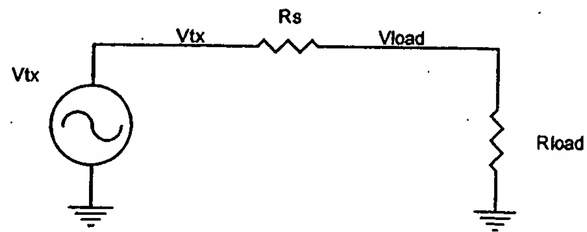

Fig. 2

Rline in this case is transformed to the secondary to Rload.

Rs value is chosen to be equal to Rload in order to get a high return loss value for the MODEM (this is a specification requirement).

The hybrid circuit for this case is shown in Fig. 3.

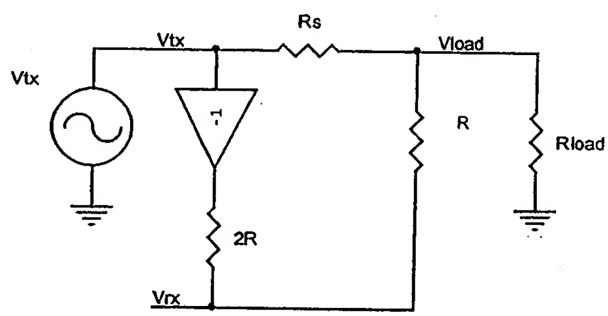

Fig. 3

The "R" resistor value is much higher than Rs (R>>Rs), so its loading of the Vload node is insignificant.

The "–1" amplifier denotes a signal taken from the complementary signal in the balanced circuit.

As Rs=Rload, Vload=Vtx/2

So, summing a sample of Vload signal through a R value resistor and a sample of –Vtx signal through a 2*R resistor, will get a null of the Vtx signal at the Vrx output.

2. **A real transformer with secondary inductance L.**

The inductance L of the transformer is connected in parallel with the Rload.

The inductor adds a Zero at the origin and a Pole at the frequency that matches the time constant of L with Rs in parallel with Rload.

The solution for this case is to modify the Vtx sample in order to get a signal that is matched in amplitude but opposite in polarity with the Vload sample.

This modification is the adding of a capacitor in series with the 2R resistor of the Vtx sample, as shown in Fig. 4.

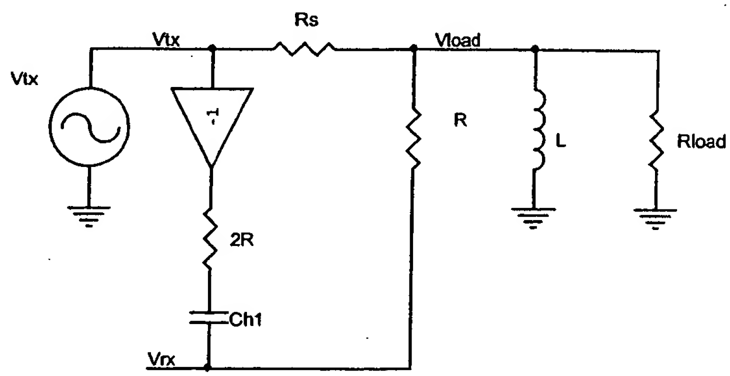

Fig. 4

3. **A real transformer and real line.**

A real twisted pair line has a characteristic impedance the is complex and is a function of frequency.

A simple model of the input impedance of a twisted pair line is shown in Fig. 5.

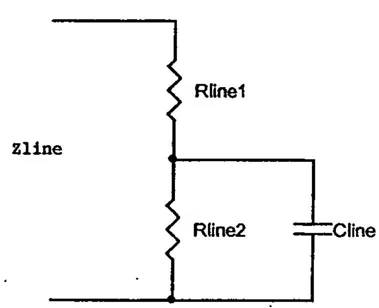

Fig. 5

There is variability of the exact characteristic impedance of twisted pair lines according to their physical parameters, so in real life there are differences between lines used in different countries and different lines within each country. The design of the hybrid has to take count of the typical line impedance for the specific customer buying the MODEMS.

In order to find a solution for the hybrid, there is a need to understand the implications of the varying impedance of the line.

The transmit circuit for th[illegible]ad is shown in figure 6.

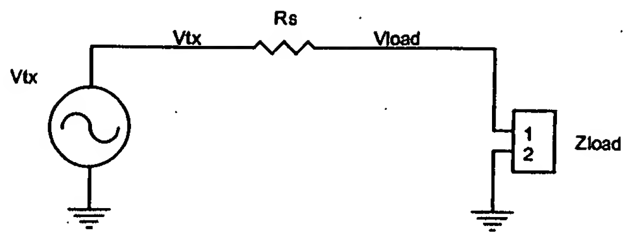

Fig. 6

Looking at the line model, Fig. 5, it is apparent that the magnitude of the load impedance decreases as the frequency increases. This means that the Vload sample (The current through R into Vrx node) in the hybrid circuit also decreases as the frequency increases. If the Vtx sample is made to behave in a similar way, the hybrid will retain its Vtx rejection as before.

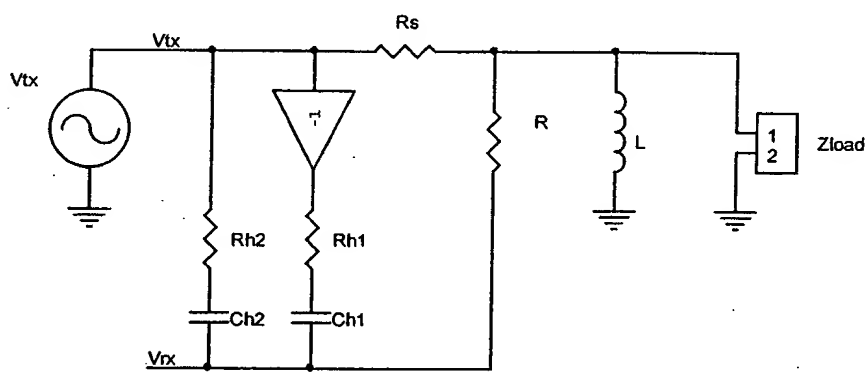

Fig. 7

Fig. 7 shows the final hybrid circuit.

The Vtx main sample is the branch with the "-1" amplifier, Rh1 and C1. A secondary Vtx sample branch is connected from Vtx to Vrx node. This branch has Rh2 and Ch2 with a higher critical frequency (lower RC factor), a higher value of Rh2 compared to Rh1 and it does not contain an inverting amplifier, so its current subtracts from the Vtx main sample branch current. The subtraction is lower at low frequency and higher at high frequency, so the net Vtx sample decreases as the frequency increases, which was the goal.

This hybrid circuit is the final circuit that compensates for the transformer inductance and the real life line impedance.

4. **Final balanced hybrid circuit.**

The final balanced circuit is shown in figure 8.

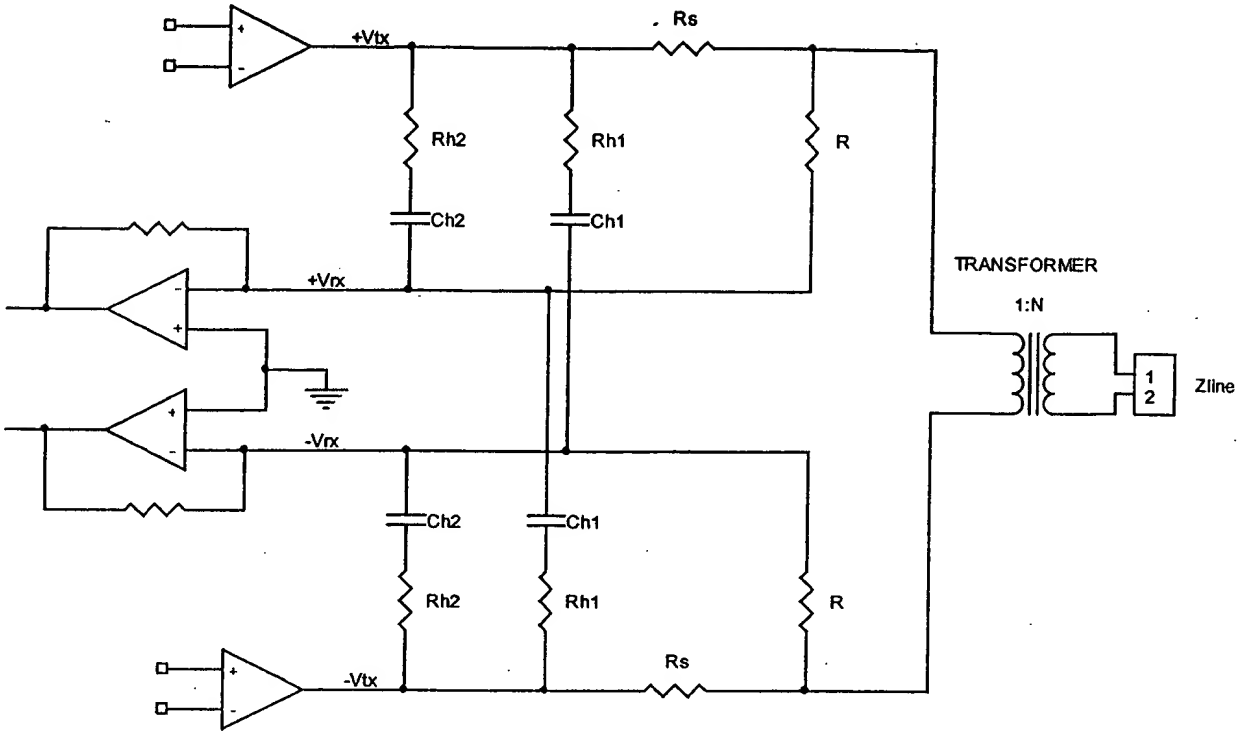

Fig. 8

Some notes about the design:

- R should be much larger than Rs for minimal loading.
- Transformer inductance is chosen according to the lowest working frequency.
- Rh1 is lower than Rh2.
- Rh1 Ch1 critical frequency (transformer compensation), is lower than Rh2 Ch2 critical frequency (line compensation).
- As the two critical frequencies of the two RC branches are not at a large distance, it is not possible to compute one branch independent from the other and also taking in count that the real line has a non analytical derived impedance but an impedance table, the final values of Rh1, Rh2, Ch1 and Ch2 are best found with computer simulation and optimization.

From: George Macdonald
To: internet:orckit.com:victork
Date:
Subject: Hybrid for modem patent

REDACTED

Hello Victor,

I am drafting the patent application for your hybrid circuit and I have some questions regarding your disclosure dated that I hope you can help me with.

Thank you for your assistance.

George Macdonald
Tel: 212-527-7700
Fax:212-753-6237
email: gmacdona@darbylaw.com

REDACTED

CC: internet:orckit.com:aviv, PYANNEY